

## EXHIBIT 2

BEST AVAILABLE COPY

Page 9 of 23

6117  
9123

# FAX NOTE

Duncan - here are some words for you to pass through to your patent attorney. It is my hope that these ideas form the basis for a patent.

Please let me know how I can help get this patent written and assigned to ATMI.

Bruce

Copy to MAT -  
JEB -  
1/9/95



Created using WinFax PRO 3.0 Desktop Technology Inc.

To: Duncan Brown
From : Bruce Baretz
Pages: 14
For information Call: Bruce Baretz
At: 201-728-3102
Fax Number : 201-728-3102

b4b  
10/23

Form: Bruce Baran, Tel: 603-886-8888

Date: 1/23/05 Time: 04:48:12

Page 3 of 16

# RTMI Record of Invention #95-2 ATMI File No. 198

White Light Emitting Diodes Based on Fluorescent Impregnation

Invention Report

Prepared by: Bruce Baran, Koen Sekutona, Inc. on Jan 7, 1998

## 1. What Is It?

The invention refers to the utilization of a single source (typically monochromatic) light emitting diode die that activates (photoexcites) the ground state of suitable fluorophore encapsulated in a polymeric matrix (or otherwise placed in a non active region of a light emitting diode assembly) whereby these fluorophore, after photoexcitation, re-emit their absorbed energy at a wavelength and wavelengths bathochromic to the initial wavelength of emission coming from the active layer of the light emitting diode.

## 2. Why Is It Useful?

a. The invention allows for the use of a single light emitting diode die to emit light with "white" coloration without requiring the manufacturing of a complex set of diode dies or subassemblies, as white light emission is presently obtained by the simultaneous utilization of red, green and blue light emitting diode dies. In this invention, the white light emission can be obtained using a single light emitting diode die and a composition of a single or mixture of suitable fluorophore that emit a broad range of wavelengths thereby offering a white light. Further, these fluorophore can be selected in a manner that allows for different hues of white to be manufactured by a simple adjustment of the concentrations of the fluorescent compositions.

b. The invention also allows for the development of a single light emitting diode die, perhaps in the ultraviolet or in the blue, that can be used to prepare light emitting diode lamps of virtually any coloration or wavelength, including all shades and hues of white. Further, the invention allows for the preparation of broad band emitting light emitting diode lamps, as opposed to the current situation where monochromatic light is typically obtained.

c. The invention allows for the utilization of light of any color and provides for a shift of the light emission to a desired spectrum, without a loss of light intensity, provided fluorophore with fluorescent quantum yields of 1.0 are utilized. Allows for better color matching of LED lamps with incandescent lamps they are designed to replace, without requiring a substantial redesign of the p-n junction.

## 3. What Materials Show It?

*Read and  
understood  
Jan 11/23  
1-0-95*

*6110  
11/23*

From: Kean, Robert T. To: Duane, Robert

Date: 06/06/2005 Time: 08:44:28

Page 8 of 14

Kean Solutions, Inc.

Patent & Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation  
01/08/95 Date: 01-07-95

In the present invention, fluorescent dyes developed for the polymer industry are believed to provide a suitable mixture of emission to generate white light. Further, light emitting diode dies based on GaN and SiC active layers are thought to provide suitable activation wavelengths to cause the generation of white light.

4. Prior Art (Some relevant prior art. Full compendium is a database search submitted to AT&T on 12-20-94).

a. white LEDs -

- I. TI White light-emitting organic electroluminescent devices using the poly(N-vinylcarbazole) emitter layer doped with three fluorescent dyes.  
AU Kido, J. (Department of Materials Science and Engineering, Yamagata University, Yonezawa, Yamagata 992 (Japan)); Horigawa, K. (Department of Materials Science and Engineering, Yamagata University, Yonezawa, Yamagata 992 (Japan)); Chayama, K. (Department of Materials Science and Engineering, Yamagata University, Yonezawa, Yamagata 992 (Japan)); Nagai, K. (Department of Materials Science and Engineering, Yamagata University, Yonezawa, Yamagata 992 (Japan)).

SO Appl. Phys. Lett. (14 Feb 1994) v. 64(7) p. 815-817  
Current Physics Microform No.: 940132158  
ISSN 0003-6951; CODEN APPLAB

CY UNITED STATES

DT Journal

TO Experimental

LA English

AB White light-emitting electroluminescent devices were fabricated using poly(N-vinylcarbazole) (PVK) as a hole-transporting emitter layer and a double layer of 1,2,4-triazole derivative (TAZ) and tris(8-quinolinolato)aluminum(III) complex (Alq) as an electron transport layer. The PVK layer was doped with fluorescent dyes such as blue-emitting 1,1,4,4-tetraphenyl-1,3-butadiene, green-emitting coumarin 6, and orange-emitting DCM 1. A self structure of glass substrate/indium-tin-oxide-doped PVK/TAZ/Alq/Mg:Ag was employed. White emission covering a wide range of the visible region and a high luminance of 3,400 cd/m<sup>2</sup> were obtained at a drive voltage of 14 V.

- II. TI Visible electroluminescence from mu-e-SiC/porous Si/Si p-n junctions.  
AU Minura, H.; Futagi, T.; Matsumoto, T.; Katsuna, M.; Ohta, Y.; Kiamura, K. (Electron. Res. Labs., Nippon Steel Corp., Kawasaki, Japan)

SO International Journal of Optoelectronics (March-April 1994) vol.9, no.2, p.211-15, 17 refs.  
P/iss: CCCC 0952-5432/94/510.00  
CODEN: IJOEVI ISSN: 0952-5432

DT Journal

TO Experimental

CY United Kingdom

LA English

DN A8419-7680F-007; B9410-4280D-010

AB We have fabricated two kinds of Si light emitting diodes (LEDs) consisting

BHB  
1/21/23

From: Minnie Suzuki Via: Unusual Search

Date: 1/10/05 Time: 08:45:47

Page 4 of 14

Kenn Solutions, Inc.

Patent & Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation.  
01/08/95 Date: 01-07-95

of n-type microcrystalline silicon carbide ( $\mu$ c-SiC)/porous silicon (PS)/p-type crystalline silicon (c-Si) p-n junctions and demonstrated a visible light emission from them. We have observed three types of visible light emission: a very weak white light emission at a forward current of about 90 mA mm<sup>-2</sup> and a strong orange-red light emission at a forward current from 200 to 819 mA mm<sup>-2</sup> for the Si LED using a 3.5-4.5  $\Omega$ cm c-Si substrate, and a uniform red light emission at a forward current above 12 mA cm<sup>-2</sup> for the Si LED using a 0.2-0.4  $\Omega$ cm c-Si substrate.

AN 92:4211891 INSPEC DN B9209-4260D-010

TI Amorphous carbon based blue light electroluminescent device.

AU Yoshida, M.; Shimizu, H.; Hatori, K.; Okamoto, H.; Hamakawa, Y. (Fac. of Eng. Sci., Osaka Univ., Japan)

SO Optoelectronics - Devices and Technologies (June 1992) vol.7, no.1, p.69-81. 20 refs.

CODEN: ODTEEG ISSN: 0912-6434

DT Journal

TC Product; Experimental

CY Japan

LA English

DN B9209-4260D-010

AB Blue light emission has been observed in hydrogenated amorphous carbon (a-C:H) based multilayered thin-film electroluminescence (EL) mode structure. The device is composed of a-C:H/a-SiC:H active layers sandwiched between hydrogenated amorphous silicon nitride (a-SiN:H) insulating layers, all of which are prepared by RF plasma chemical vapor deposition. A series of technical data on the device performance, including luminance, transferred charge density and emission spectrum are presented. Developed devices exhibit a broad band white light emission having a luminance up to 20 cd/m<sup>2</sup>. However, purity of emission color is remarkably improved by insertion of a-SiC:H layer in the middle of the active a-C:H layer.

II AN 92:4234151 INSPEC DN B9210-4260D-012

TI Amorphous thin film white-LED and its light-emitting mechanism.

AU Chen Zhiming; Sun Guosheng; Pu Hongbing (Shandong Inst. of Mech. Eng., Jinan, China)

SO Conference Record of the 1991 International Display Research Conference (Cat. No.91CH3071-8)

New York, NY, USA: IEEE; 1991. p.123-6 of vi+267 pp. 4 refs.

Conference: San Diego, CA, USA, 15-17 Oct 1991

Sponsor(s): IEEE; SID; Advisory Group Electron Devices

Price: CDOC CH3071-8/91/0000-0123\$01.00

ISBN: 0-7803-0213-3

DT Conference Article

TC Product

CY United States

LA English

DN B9210-4260D-012

AB Thin film light-emitting diodes (TFLEDs) made of amorphous semiconductor silicon carbide (a-SiC:H) have been developed by glow discharge deposition in an  $\text{SiH}_4\text{-CH}_4$  mixture. White light emission is observable in the samples with a structure of either glass/ITO/a-SiC:H/Al or glass/ITO/p-I-n a-SiC:H/Al when a proper critical condition has been established. The light-emitting mechanism associated with these LEDs is suggested to be an

6/10  
13/23

From: Bruce Baker: To: Duncan Gray

Date: 1/3/96 Time: 08:47:50

Page 5 of 14

Kean Solutions, Inc.

Patent & Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation  
01/02/95 Date: 01-07-95

radiative recombination of the electrons in the extended states of the conduction band and the holes in the localized states of the valence band.

M. AN 92(10):133561 COMPENDEX DN 9210131355

TI Amorphous thin film white-LED and its light-emitting mechanism.

AU Chan, Zhiming; Sun, Guosheng; Pu, Hongbing

MT Conference Record of the 1991 International Display Research Conference.

MO IEEE Electron Devices Soc; Society for Information Display; Advisory Group on Electron Devices

ML San Diego, CA, USA

MD 15 Oct 1991-17 Oct 1991

SO Conference Record of the 1991 International Display Research Conference

Conf Record of Int Display Res Conf Publ by IEEE, IEEE Service Center,

Piscataway, NJ, USA (IEEE cat n 91CH3071-5), p 122-125

ISBN: 0-7803-0213-3

PY 1991

MN 16905

DT Conference Article

TC Experimental; Theoretical

LA English

AN 92(10):133561 COMPENDEX DN 9210131355

AB: Thin film light-emitting diodes (TFLEDs) made of amorphous semiconductor silicon carbide (a-SiC:H) have been developed by glow discharge deposition in an  $\text{SiH}_4$  plus  $\text{CH}_4$  mixture. White light emission is observable in the samples with a structure of either glass/ITO/a-SiC:H/Al or glass/ITO/p-n a-SiC:H/Al when a proper critical condition has been established. The light-emitting mechanism associated with these LEDs is suggested to be an radiative recombination of the electrons in the extended states of the conduction band and the holes in the localized states of the valence band. 4 Refs.

v. AN 91(17):55809 PHYS

TI Blue-emitting electroluminescent phosphors: review and status.

AU Lutch, S. (DevTech Inc., Princeton, NJ (USA)); Morton, D.C. (U.S. Army Electronics Devices and Technology Lab., Fort Monmouth, NJ (USA))

NR Ph-470

SO 5. International Workshop on Electroluminescence.

Leskela, M. (Turku Univ. (Finland); Helsinki Univ. of Technology

(Finland)); Nylanen, E. (Helsinki Univ. of Technology (Finland)) (eds.)

Finnish Academy of Technology, Helsinki (Finland)

1990 p. 137-143 of 315 p.

Acta Polytech. Scand., Appl. Phys. Ser.no. 170

Conference: 5. International Workshop on Electroluminescence (EL-5).

Helsinki (Finland), 11-13 Jun 1990

ISBN 0355-2721; CODEN AP55D; ISBN 951-655-317-5

CY FINLAND

DT Miscellaneous; Conference

TC Experimental

LA English

AB While TFEL has made enormous strides in the last several years, the weak point in achieving a high luminance display is the continued lack of an efficient blue-emitting electroluminescent phosphor. This paper reviews the

PHB  
14/23

From: Vince Burtiz To: General Search

Date: 1/10/05 Time: 08:45:25

Page 6 of 14

Keen Solutions, Inc.  
Patent & Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation  
01/08/95 Date: 01-07-05

field of blue-emitting EL phosphors, and presents research results on one of the possible candidates for TFEL displays.

vi. AN 90-3633232 INSPEC DN B90040508  
TI Toward a visible light display by amorphous SiC:H alloy system.  
AU Hamakawa, Y.; Kruangam, D.; Toyama, T.; Yoshimi, M.; Patacho, S.; Okamoto, H. (Fac. of Eng. Sci., Osaka Univ., Japan)  
80 Optoelectronics - Devices and Technologies (Dec. 1988) vol.4, no.2, p.281-94, 25 refs.  
CODEN: OTEERG ISSN: 0012-6434

DT Journal  
TC Practical; Experimental  
CY Japan  
LA English  
DN B90040508

AB A series of experimental trials to realize flat panel display devices using plasma CVD-produced a-Si<sub>1-x</sub>C<sub>x</sub>H alloy has been reported. Fabrication technology and basic properties of the active material a-Si<sub>1-x</sub>C<sub>x</sub>H alloy are briefly introduced. Then the technical data on both injection type and intrinsic type EL devices are presented. The injection type EL device (LED) has a basic structure of p(a-SiC<sub>x</sub>H)/n(a-SiC<sub>x</sub>H)/n(a-SiC<sub>x</sub>H), and the emission color can be controlled from red to green by adjusting the carbon content x in the a-Si<sub>1-x</sub>C<sub>x</sub>H luminescent layer. The luminance of 20 cd/m<sup>2</sup> was obtained from the yellow LED with a forward injection current density of 600 mA/cm<sup>2</sup>. The intrinsic EL device (TFEL) shows a luminance of 30 cd/m<sup>2</sup> for the blue color emission and 40 cd/m<sup>2</sup> for white light so far. The developed devices have some significant advantages over the conventional crystal LEDs: wide area, ease of fabricating integrated type multi-color or tunable color LEDs, and low cost. Utilizing these characteristics, new types of optoelectronic functional elements are proposed and discussed.

vii. AN 88(16):77843 PHYS  
TI White light emitting thin-film electroluminescent devices with SrS:Ca, Cl/ZnO:Mn double phosphor layers.  
AU Tanaka, S.; Mikami, Y.; Deguchi, H.; Kobayashi, H. (Dept. of Electronics, Tottori Univ. (Japan))  
60 Jpn. J. Appl. Phys., Pt. 2 (Mar 1986) v. 25(3) p. L225-L227  
ISSN 0021-4922; CODEN JAPLD

CY JAPAN  
DT Journal  
TC Experimental  
LA English

AB White light emitting thin-film electroluminescent devices have been fabricated. The devices consist of double phosphor layers of a greenish-blue light emitting SrS:Ca, Cl and a yellowish-orange light emitting ZnO:Mn. A brightness level of 1100 cd/m<sup>2</sup> at 5 kHz drive has been obtained. (orig.)

viii. AN 92-366485 [44] WPINDEX  
DN N92-379300  
TI Tunnel junction multiple wavelength light-emitting diode for display system - has p-n junctions with different band gaps which may be collectively energized.

15723

From: Bruce Beretz To: Duncan Broad

Date: 1/26/05 Time: 08:09:46

Page 7 of 14

Keen Solutions, Inc.

Patent &amp; Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation

01/08/95 Date: 01-07-95

DC U12 U13

IN KURTZ, S R; OLSON, J M

PA (MIDE) MIDWEST REG INST

CYC 34

PI WO 9217909 A1 921015 (9244)\* EN: 11 pp

RW: AT BE CH DE DK ES FR GB GR IT LU MC NL OA SE

W: AT AU BB BG BR CA CH DE DK ES FI GB HU JP KP KR LK LU MG MW NL NO

PL RO RU SD SE US

US 5168781 A 921124 (9250) 6 pp

AU 9217577 A 921102 (9305)

ADT WO 9217909 A1 WO 92-US2281 920323; US 5168781 A US 91-678230 910401; AU

9217577 A AU 92-47577 920323; WO 92-US2281 920323

FDT AU 9217577 A Based on WO 9217909

PRAI US 91-678230 910401

AN 92-368485 (44) WPIINDEX

AB WO 9217909 A UPAS: 931006

A multiple wavelength light-emitting diode has a monolithic cascade cell structure comprising at least two p-n junctions with GaInP2/GaAs as top/bottom cells. This gives each junction different band gaps.

An electrical connection is then structured in place so that all of the p-n junctions are simultaneously energized to emit corresponding wavelengths or colours. A transparent tunnel p-n junction of GaAs n+GaAs p+ interconnects the diodes.

ADVANTAGE - Provides three primary colours or emits them simultaneously to produce white light in a display.

3/5

ABEQ US 5168781 A UPAS: 931006

The multiple wavelength light emitting diode comprises a multiple layered, single structure of several LEDs of varying band gaps, and is made by depositing thin films of alternating p-doped and n-doped materials, wherein the lowest band gap material is deposited first and the highest band gap material is deposited last. Electrical connections are then structured in place so that all of the n-p junctions can be collectively energized to emit simultaneously the corresponding wavelengths or colours. The device may be utilized to provide the three primary colours or emit them simultaneously to produce white light.

USE - LED visual display of more than one colour.

2/5

IL AN 79-72319B (40) WPIINDEX

TI White light emitting diode or triode - having semiconductor and semiconductor oxide layers and metal contact pad so that light appears as halo around pad.

DC L03 U12 U14 X25 X26

IN BAYRAKTARO, B M; HARTNAGEL, H L

PA (BAYR-1) BAYRAKTAROGU B

CYC 1

PI GB 2017409 A 791003 (7940)\*

PRAI GB 78-11432 780322; GB 79-13930 790420

AN 79-72319B (40) WPIINDEX

AB GB 2017409 A UPAS: 930901

An LED emitting white light when reverse biased comprises (a) a semiconductor, (b) a layer of semiconductor oxide on said semiconductor and

BIB 14/23



From: Bruce Haratz To: Duncan Smith

Date: 1/6/95 Time: 08:51:08

Page 8 of 14

Kean Solutions, Inc.

Patent & Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation  
01/08/95 Date: 01-07-95

(e) a metal pad on the oxide. A double oxide LED comprises an LED as above having a layer of Al<sub>2</sub>O<sub>3</sub> between the metal pad and an oxide of the semiconductor. The Al<sub>2</sub>O<sub>3</sub> oxide of the semiconductor are both 20-70 angstroms thick.

A light emitting triode comprises an LED as above, with a second metal pad spaced from the first metal pad and contacting the semiconductor oxide. Preferably, the semiconductor is Si, having ample superficial trap density or III-V or II-VI semiconductors, esp. n-type GaAs.

The light appears as a halo round the pad and is continuous over the visible spectrum and into the infrared. For luminescence over an area a grid electrode or very thin electrode may be used. Typical temp. range of operation is 77-383 K for GaAs device, with higher efficiency at lower temp.

#### b. Phosphors and LEDs - active layer

I. AN 82:4211991 INSPEC DN B8209-42800-010

T1 Amorphous carbon based blue light electroluminescent device.

AU Yoshimi, M.; Shimizu, H.; Hattori, K.; Okamoto, H.; Hamakawa, Y. (Fac. of Eng. Sci., Osaka Univ., Japan)

SO Optoelectronics - Devices and Technologies (June 1992) vol.7, no.1, p.69-81, 20 refs.

CODEN: ODTEEG ISBN: 0912-5434

DT Journal

TC Practical; Experimental

CY Japan

LA English

DN B8209-42800-010

AB Blue light emission has been observed in hydrogenated amorphous carbon (a-C:H) based multilayered thin-film electroluminescence (EL) mode structure. The device is composed of a-C:H/a-SiO<sub>2</sub>/H active layers sandwiched between hydrogenated amorphous silicon nitride (a-SiN<sub>2</sub>/H) insulating layers, all of which are prepared by RF plasma chemical vapor deposition. A series of technical data on the device performance, including luminance, transferred charge density and emission spectrum are presented. Developed devices exhibit a broad band white light emission having a luminance up to 20 cd/m<sup>2</sup>. However, purity of emission color is remarkably improved by insertion of a-SiO<sub>2</sub>/H layer in the middle of the active a-C:H layer.

I. AN 82(10):82808 PHYS

T1 Several blue-emitting thin-film electroluminescent devices.

AU Miura, Noboru; Ishikawa, Tetsuo; Sasaki, Takashi; Oka, Tochiyuki; Ohata, Hiroshi; Matsumoto, Hiroyasu; Nakano, Ryosiro (Dept. of Electronics and Communication, Meiji Univ., Kawasaki (Japan))

SO Jpn. J. Appl. Phys., Pt. 2 (15 Jan 1992) v. 31(1A/B) p. 46-48

ISSN 0021-4922; CODEN JAPLD

CY JAPAN

DT Journal

TC Experimental

LA English

AB Blue-emitting thin-film electroluminescent (EL) devices were studied. As the blue-emitting phosphor, thin-films in which the Tm<sup>3+</sup> ion was doped into several hosts (ZnS, Y<sub>2</sub>O<sub>3</sub>, CaF<sub>2</sub>, ZnF<sub>2</sub> and YF<sub>3</sub>) and CaF<sub>2</sub>:Eu were

6/1/95  
1/7/23

From: Bruce Benitz To: Duncan Brown

Date: 1/26/06 Time: 08:22:27

Page 8 of 14

Keen Solutions, Inc.

Patent & Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation  
01/08/95 Date: 01-07-86

Investigated Blue EL emission of  $Tm^{3+}$  ions arising from the  $1D_2 \rightarrow 3H_4$  or  $1G_4 \rightarrow 3H_6$  transition was observed in each  $Tm$ -doped device. The most dominant lines in these emissions varied with the kind of host materials. The  $CaF_2:Eu$  thin-film also showed blue electroluminescence due to a partly-allowed  $4f8(7F)6d \rightarrow 4f8(8S)$  transition of the  $Eu^{2+}$  ion. (orig.)

c. Upconversion - this process converts monochromatic (narrow band) light into second or third harmonics of the initial light wavelength and, hence, the efficiency of the light emission is a function of the intensity. Further, the light emission remains monochromatic and can not be used to generate white light. Further, the intensities of current light emitting diodes are not thought to be sufficient to allow for up conversion to practically take place (although the light emission from diode lasers are probably sufficient).

I AN 87:2089562 INSPEO ON A87110582; B87063351

T1 Various performances of fiber-optical temperature sensor utilizing infrared-to-visible conversion phosphor.

AU Hirano, M.; Watanabe, M.; Yasuda, H. (Ron Taisel Electron. Co, Kyoto, Japan)

SO Denki Kagaku (Feb. 1987) vol.53, no.2, p.158-64, 6 refs.

CODEN: DAKGAC2 ISSN: 0368-9287

DT Journal

TO Experimental

OY Japan

LA Japanese

ON A87110582; B87063351

AB A fiber-optical temperature sensor utilizing temperature-sensitive emission of an infrared-to-visible conversion phosphor  $YF_3:Yb, Er$  has been developed. This sensor was successfully applied to temperature measurements in the 3 MW-microwave field. The accuracy of  $\pm 0.5$  degrees C over the range of -20 degrees C to +200 degrees C was obtained. It was found that the margin of instrument error included the difference of measured temperature and previously calibrated temperature. The instrument error was compensated by calculating the correction. The precise technique to meet temperature-sensitivity of the probe with its calibration curve has been developed. The thermal drifting in the temperature indication was decreased by the stabilization of an infrared excitation with use of an LED feedback control. This is explained by the fact the efficiency of the phosphor excitation is maintained to be constant by the competitive actions of thermally induced fluctuations in intensity and wavelength of an LED emission. The competitive actions for the  $YF_3:Yb, Er$  phosphor are effective for the excitation wavelength of 940 to 950 nm.

II AN 90:177498 HCA

T1 Pulse operating up-converting phosphor LED

AU Zdanowski, Marek

C9 Inst. Electron Technol., Sci. Prod. Cent. Semicond., Warsaw, Pol.

SO Electron Technol. (1978), 11(3), 49-61

CODEN: ETNTAT; ISSN: 0070-8816

DT Journal

LA English

6 H/18123

From: Sajee Bharat, Tel: 020 6666 6666

Date: 10/05 Time: 08:55:19

Page 11 of 14

Keen Solutions, Inc.

Patent &amp; Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation

01/08/95 Date: 01-07-05

and phosphorescence, from the selected dyes, is emanating from a lambertian surface, as opposed to a point source from a single point p-n junction.

e. Development of a light emitting diode lamp using a blue or UV light emitting diode die whereby the color of the spontaneous emission can be varied as a function of ambient temperature (and, hence, the applied voltage) where the fluorescent or phosphorescent dyes emit different wavelengths of emission as a function of temperature.

f. Development of a light emitting diode lamp with a long memory of re-emission of light in such a manner that the re-emitted light continues to be observed for several hours after the applied voltage is removed by the incorporation of suitable phosphorescent materials into the encapsulating matrix.

g. Development of a light emitting diode where an electrical pulse is delivered (to minimize power drain from the battery source) but where a continuous period of illumination is realized by adjustment of the luminescence lifetimes of suitable phosphors.

h. Development of a light emitting diode where the total illuminance is increased by virtue of shifting the illumination wavelengths of any short wavelength emitting p-n junction towards the photopic maximum.

i. Development of a light emitting diode where a photochromic phosphor is used such that the illumination wavelength during day or night usage is different by virtue of using incident sunlight to adjust the chromaticity of the incorporated dye.

#### 5. Distinction from Prior Art

a. Phosphors are not incorporated into active layer thereby not impacting the inherent efficiencies of the p-n junction;

b. White light emission can be obtained using one addressable die;

c. Different shades and hues can be obtained from the same underlying diode die by modifying the encapsulating material which occurs later in the manufacturing process;

d. Colors and shades are not limited to monochromatic emissions, although they could be designed as such;

e. Efficiencies of light emission are not intensity dependant as in up-conversion.

From: [REDACTED] To: [REDACTED]

[REDACTED]

Page 14 of 17

Keen Solutions, Inc.

Patent & Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation  
03/08/95 Date: 01-07-95

f. Selection of fluorophore and phosphors are not limited to those that are compatible with active layer.

g. Incidence of illumination can be improved and broadened over a greater range than available from any other method presently used in LED fabrication;

h. Potential for testing to take place within dome?

i. Opportunity to develop ambient surface emission from an otherwise point source.

#### 6. Details of Method

a. Blue or UV light-emitting diode die, made from a GaN or SiC or any other semiconductor known to produce UV or blue light is cut;

b. Die is potted into an encapsulating dome containing mixture or specially designed fluorophore or phosphor;

c. Concentration and path length of dome is selected to maximize the emission yields and color.

#### 7. Claims

##### Patent Introduction:

Considerable efforts have been advanced in the area of developing full-color and white light emitting diode systems to replace existing illumination devices based on incandescent and fluorescent (mercury vapor) bulbs. The practical advantages of illumination devices based on light emitting diodes are many and include higher reliability, lower power consumption, shock resistance, longer illumination duration, discrete wavelengths of illumination and focused illumination output. It is important to note, however, that certain of these practical advantages can be considered design disadvantages in the context of special systems. For example, whereas the focused light output from a typical light emitting diode allows for alignment of the light intensity without requiring a sophisticated and expensive lens system, in those applications where the illumination needs to be observed across a wide face, the requirement to defocus the other illumination cone is clearly a disadvantage.

One application where light emitting diodes are beginning to become an accepted replacement for incandescent bulbs is in the area of electronic message signs used to supply advertising media as well as the current time and temperature. Many of these signs are resident in the outdoors and need to be bright

*Handwritten:*  
Jung  
1-10-95  
BHS  
21/23

Keen Solutions, Inc.

Patent & Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation  
01/08/95 Date: 01-07-05

enough to be observed in the daylight and from a suitable distance. In most cases, existing outdoor signs have relied upon incandescent lamps which, because of their broad spectroscopic illumination profile, are observed to illuminate in a white color. For these outdoor applications, the light emitting diodes provide a tremendous advantage in that their burn time is in excess of ten years, whereas incandescent frequently "burn out" and, thus, leave an empty place in the message. In real world applications, the burn out of the bulb makes the message unreadable or, at best, provides a significant maintenance component to the management of the outdoor signs.

Current usages of light emitting diodes in outdoor and other signage have been restricted to either red or amber illumination colors. Although other monochromatic colors are available, the intensity of the light emitting diode needs to be in excess of 1000 mcd and, hence, have been limited to hard to visualize colors. Further, the aesthetics of signage in monochromatic colors of red and amber have limited their acceptance as replacements for white incandescent lamps, despite the maintenance and low power consumption advantages of the light emitting diode, in general.

White light can, in theory be presented in outdoor light emitting diode assemblies, but presently, the broad band illumination necessary to provide white light requires the use of many light emitting diode lamps incorporated into complicated LED modules. In many cases, the modules contain at least 9 and up to 22 components where blue, green and red light emitting diode lamps are electrically powered and manipulated in such a manner as to provide the appropriate balance of monochromatic light blended in such a manner as to provide a white light source. The high cost and low efficiency of these modules make them relatively unattractive as replacements for single incandescent white lamps and hence, the availability of white light emitting diode lamps, especially based on single semiconductor dies, are highly wanted.

It is the claim of this invention that single semiconductor dies can be incorporated into a simple light emitting diode "pot", that has been incorporated with fluorescent organic and inorganic fluorophores and phosphors that take within the blue or ultraviolet radiation of the pot and provide a substantial series of benefits. One major unexpected advantage of using this process to attenuate the monochromatic light normally emitted by a light emitting diode is the development of a simple device that yields a broad band emission, in total, bathochromic to the initial wavelength of emission, and is emitted with the appearance of white light. Further, this invention will allow for the direct replacement of simple incandescent white lamps with simple, single light emitting diode lamps that similarly provide a white light emission but which incorporated all of the other advantages of light emitting diodes.

**Keen Solutions, Inc.**  
**Patent & Prior Art Search: White Light Emitting Diodes based on Fluorescent Impregnation**  
**01/08/95 Date: 01-07-95**

PHN  
23123

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☒ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**